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Effect of Copper-based Fillers Composition On Spreading and Wetting Behaviour

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Abstract. Wetting and spreading of molten brazing filler material are important factors that influence the brazing ability of a joint to be brazed. Several investigations into the wetting ability of a brazing filler alloy and its spreading area in the molten state, in addition to effects of brazing temperature on the contact angle, have been carried out. Generally, the composition of copper-based filler and temperature affect spreading of molten brazing filler material during brazing. Wetting by and interfacial reactions of the molten brazing filler material with the metallic substrate, especially, affect strongly the spreading of the filler material. In this study, the effects of filler composition and brazing temperature on the spreading of molten brazing filler metallic alloys were investigated. MBF 2005 (Cu, 5.7wt.%Ni, 9.7wt.%Sn, 7.0wt.%P), MBF 2002 (Cu, 9.9wt.%Ni, 4.0wt.%Sn, 7.8wt.%P) and VZ 2250 (Cu, 7.0wt.%Ni, 9.3wt.%Sn, 6.3wt.%P) alloys were used as brazing filler materials. Pure copper block and a rectangular plate were employed as the base metal. Brazing filler material and metallic base plate were first washed with acetone. Brazing was performed at 750°C and 800°C under Ar gas for 30 minutes using an electrically heated furnace, after which, the original spreading area, defined as the sessile drop area, and the apparent spreading area were both evaluated. It was observed that the spreading area and wetting angle influenced by the composition of copper-based filler.

1. Introduction

Brazing of copper joints is used extensively in the heat exchanger, EGR cooler, and dissimilar-metal joining. Studies found that the important factors for getting a good joint ability are influenced by the filler material properties, wetting and spreading by molten filler metal and the interfacial reactions between the molten filler and interfacial reactions between base materials and filler materials [1, 2]. A sound brazed joint generally results when an appropriate filler alloy is selected, surface cleanliness, metal and flux inclusions, different melting temperatures of the components, cooling rate of the joint, excessive alloying of the brazing metal, improper joint design, and tolerances [3]. Different percentage of the composition may influence the wetting ability of the filler on the base material. Fluxing is used except when an atmosphere is specifically introduced into the furnace to perform the same shielding gas. Furnaces are either batch or continuous types with possibly atmosphere controls and should have automatic time and temperature [6, 7].

Other than that, different values of temperature are investigated [4]. Temperature has big influences in microstructure and strength in brazing [8,9]. The higher the temperature gives the higher strength of joining [10]. These two factors will distribute the spreading area and the wetting angle of the molten fillers. High brazing temperatures inhibit the joining to the base metal, and the fluidity of brazing filler metals diminishes with increasing Cu content [5]. Apart from that, the joint strength will be affected by these two factors. Thus, the spreading area and wetting angle have been carried out to investigate the joint strength of the copper based fillers.

However, lack of studies explained the relationship between the individual element in fillers of copper brazing and the temperature of brazing. Thus, in this project, a study of the relationship of the elements in fillers and the temperature of brazing on filler spreading and wettability will be conducted.

2. Experimental Procedure

The specimens used was a copper plate and copper block. The copper plate was cut into rectangular shape and it was used for spreading method. The copper block was placed together into T-shape and it was used for the wetting method. The fillers for spreading method were cut at same weight which was approximately, 0.0040 g - 0.0042 g. The weight percentage of composition of the copper based fillers metals are listed in Table 1. The specimens were washed by acetone before it was placed into furnace brazing. The specimens were placed together in a ceramic boat into furnace brazing with the presence of argon gas as shielding gas to avoid oxidation at the flowrate of 1.0 l/min. The temperature used is 750°C and 800°C as manipulated parameter and the holding time of furnace brazing is 30 minutes. After the brazing was done, the specimens undergo the cold mounting process by using epoxy powder. Since the pure copper is soft, cold mounting is preferable than using hot mounting. After the cold mounting was fully cured, the specimens were grinded from 320 grit until 4000 grit. The specimens were grinded until the surface of wetting and spreading appears. Lastly, the specimens were polished by using the polishing pad until 0.5 μm grit. After polishing was done, the optical microscope was used to observed and captured the spreading of molten filler and the wetting of the filler. The method to calculate the spreading area was by using perimeter gridline. The wetting angle was found by using the method of right angled triangle.

Table 1. Chemical composition (wt. %) of the copper based filler metal.

Filler metal	Cu (wt.%)	Ni (wt.%)	Sn (wt.%)	P (wt.%)
MBF 2005	77.6	5.7	9.7	7.0
MBF 2002	78.3	9.9	4.0	7.8
VZ 2250	77.4	7.0	9.3	6.3

3. Results and Discussion

3.1. Spreading Area

Spreading test results are shown in Figure 1 and Figure 2. According to these results, filler material composition influences the original spreading areas and the temperature influences the spreading ability of the copper-based filler material.

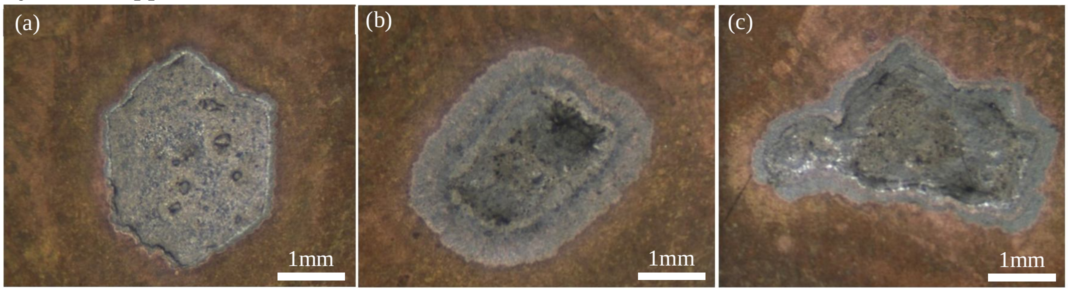

Figure 1. Spreading area for 750˚C for copper-based filler material; (a) MBF 2005, area:12.88 mm², (b) MBF 2002, area:15.50 mm² and (c) VZ 2250, area:17.25 mm².

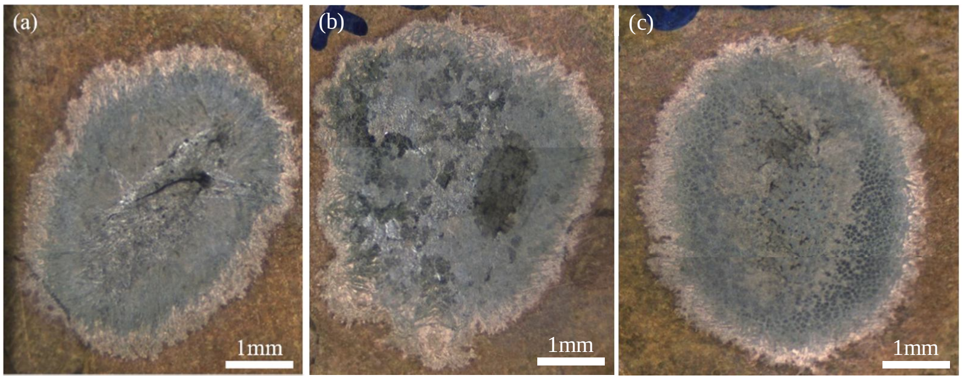

Figure 2. Spreading area for 800˚C for copper-based filler material; (a) MBF 2005, area: 48.00 mm², (b) MBF 2002, area: 58.00 mm² and (c) VZ 2250, area: 61.00 mm².

From the figure 1, the result shows that MBF 2005 have the lowest spreading ability. The filler is fully deposited on the surface of base metal but still have a contact surface on the base metal. MBF 2002 also not completely molten but the spreading area of MBF 2002 is higher than MBF 2005. For VZ 2250, the molten part of the filler is lower than MBF 2002 but it has the largest spreading area. The deposited part of VZ 2250 is higher than MBF 2002 and MBF 2005. Compared with figure 1, figure 2 shows that all the fillers are molten at 800 ˚C. This is due to the composition of the filler which is VZ 2250 have quite balance percentage of Ni, Sn, and P. The balanced composition in VZ 2250 encourage the filler to provide highest spreading area. According to J. Li from his journal, contain higher Sn in filler composition will increase pitting for the joints but it inhibits the filler to spreading at the molten base [10]. It is shown in filler MBF 2005 at 800 ˚C which is, the higher the Sn composition will have lowest spreading area. MBF 2002 and VZ 2250 still have a small amount of deposited filler on the base metal. It is not completely molten due to the different percentage of filler composition. Thus, from both figure, higher or lower percentage of certain composition does not influence the ability to spread.

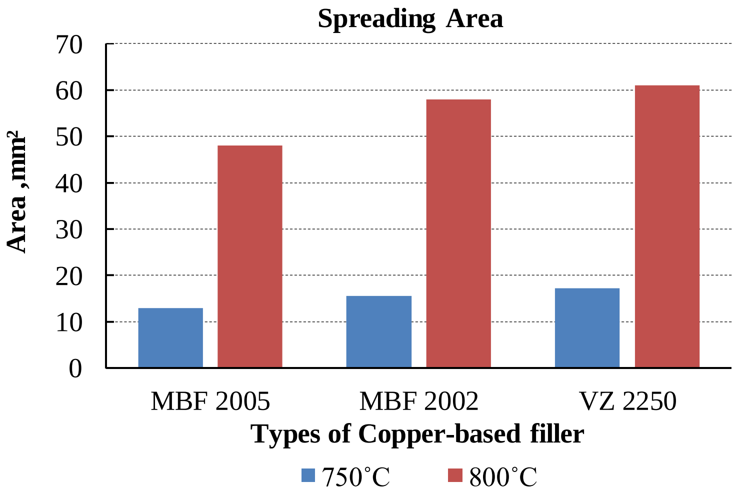

Figure 3. Spreading Area with Different Temperature.

Figure 3 shows the difference of spreading area between the temperature. According to the graph, we can relate that composition of the copper-based filler and the temperature of the furnace brazing give high influences to the spreading area of the molten filler. The higher the temperature of furnace brazing, the bigger the spreading area of the molten fillers. For the filler of MBF 2005, the highest percentage of other filler, it gives the lowest of the ability to spread on the base metal. The present of the highest percentage of P in MBF 2002, it increases the spreading ability of MBF2002 more than MBF 2005. Since the percentage of phosphorus in any particular alloy has a marked effect on its temperature (the temperature at which it becomes fully molten) and hence it's flow characteristics. The closer an alloy's phosphorus content is to the eutectic composition, the better its flow properties. In addition, small changes in phosphorus content can also have a marked effect on an alloy's flow properties. VZ 2250 has present of the phosphorous, it contributes the fluidity at a fast rate. An increase in phosphorous content increases the fluidity of the liquid metal. More fluid alloy requires a looser-fitting space to allow capillary attraction to retain the liquid. Thus, the higher the temperature, the bigger the spreading area.

3.2. Wetting Angle

Figure 4 and figure 5 shows the wetting angles of the copper-based filler materials with different temperatures. According to the results, there are slight differences in wetting angle of the filler. In other words, the temperature also gives influences to the wetting ability of the molten filler

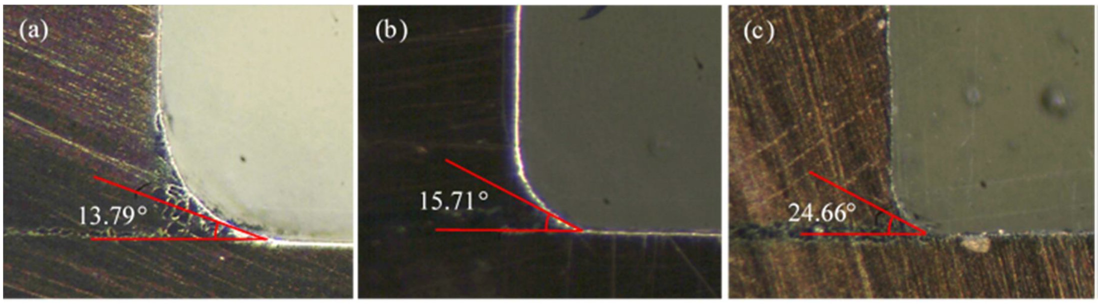

Figure 4. Wetting angle for 750˚C for copper-based filler material; (a) MBF 2005 (b) MBF 2002 and (c) VZ 2250.

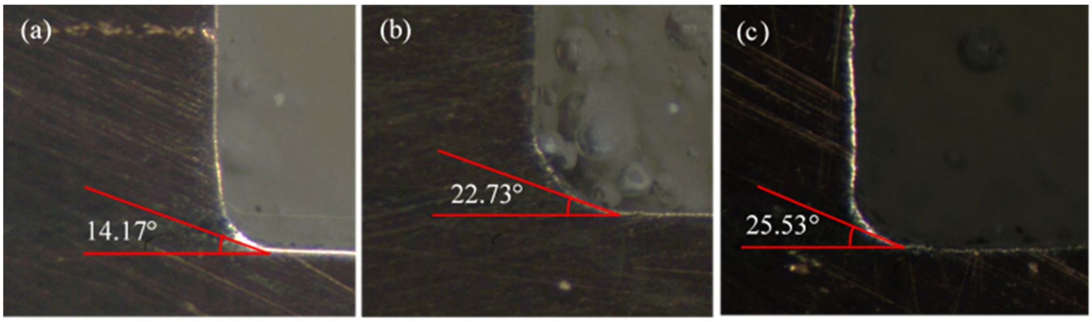

Figure 5. Wetting angle for 800˚C for copper-based filler material; (a) MBF 2005 (b) MBF 2002 and (c) VZ 2250.

From the both figures above, the result shows that MBF 2005 have the lowest wetting angle and VZ 2250 has the higher wetting angle. Compared to the both temperature, the wetting angles slightly increase from 750˚C to 800 ˚C. Due to different percentage composition of the filler, the resulting wetting angle also affected. MBF 2005 has higher contain of Sn but low contain of Ni among these three fillers but MBF 2002 has high contain of Nickel and very low contain of Sn. These shows that high or low in composition percentage do not give good wetting ability. Unlike VZ2250, it has quite a similar percentage of Ni, Sn and P composition. These differences in composition affects the wetting ability of the copper-based fillers.

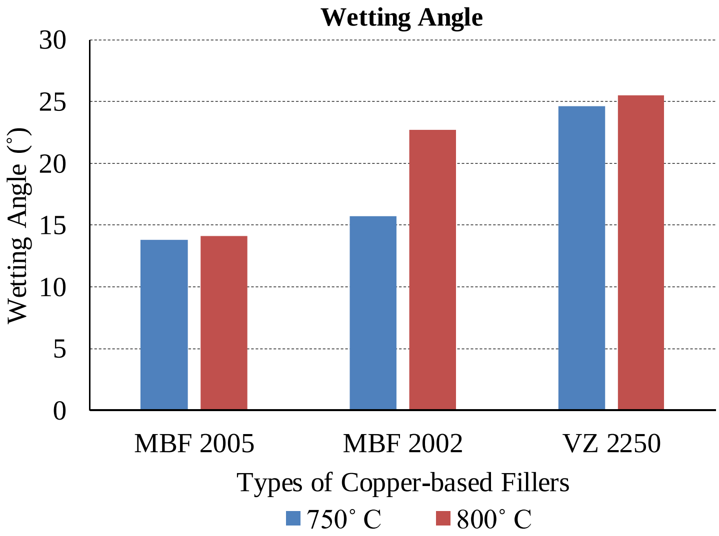

Figure 6. Wetting Angle with Different Temperature

From the figure above shows the relationship between wetting angle and temperature of furnace brazing. Wetting angle increase with increasing the temperature of the brazing. Since Nickle is to enhance the strength and hardness to the filler and Sn is to reduces friction and improves braze ability of the filler, thus the higher percentage of Ni and Sn will contribute the higher wetting angle of the copper-based fillers. The present of high Ni and Sn will inhibit the filler to get a higher wetting angle. VZ 2250 has quite balancing in composition Ni, Sn, and P contain. As shown in Table 1, the percentage of composition from copper-based fillers gives effect on wetting ability between fillers and base plate. This result shows that the balance percentage in the composition provides good wetting ability.

4. Conclusion

In this study, the effect of Copper-based fillers composition on spreading and wetting angle is investigated. The results as follows:

- The spreading area increased with increasing the brazing temperature
- The wetting angle is higher with increasing the brazing temperature
- The wetting and spreading are affected by the different percentage composition in copper-based filler metal. However, the pros and cons in the percentage of composition filler material will exhibit wetting and spreading ability. Thus, the same average of percentage in filler composition is needed to provide good wetting and spreading ability.

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